

Climate Variability, Hydrology, and Flooding



Introduction to NASA Remote Sensing Missions,
Earth System Models, and Data Access Tools
Relevant for Monitoring Climate Variability and Flooding



Objective

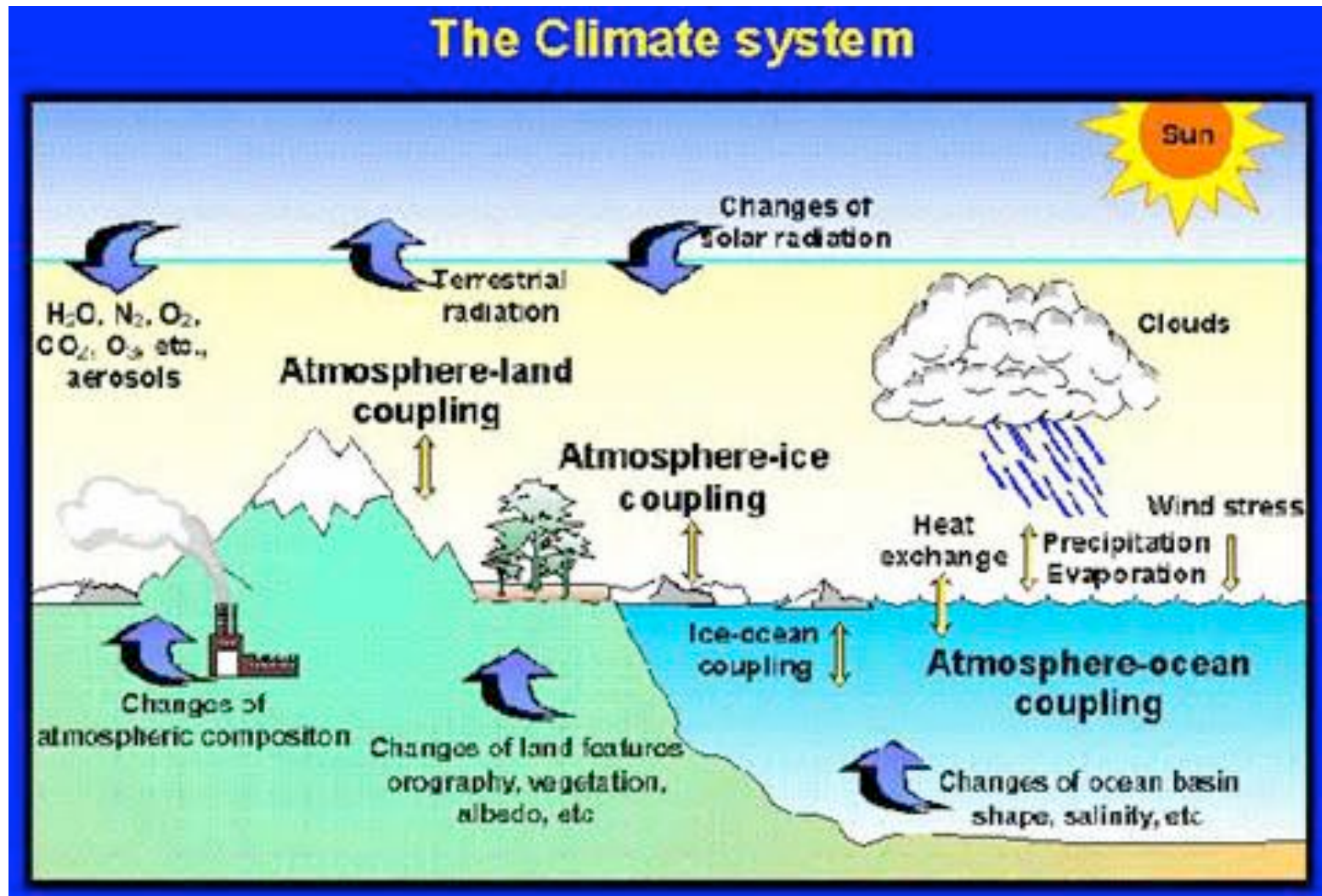
To introduce NASA satellite missions and Earth Science (ES) Models, and Data Access Tools used in this Training on Climate, Hydrology, and Flood (CHF) Monitoring

Outline

- Geophysical Quantities used for Climate, Hydrology, and Flood (CHF) Monitoring
- NASA Satellite Missions for CHF Monitoring
- NASA Earth Systems Models for CHF Monitoring
- Data Search, Access, Analysis, and Visualization Tools - [Focus Giovanni](#)

Geophysical Quantities Used for Climate, Hydrology, and Flood (CHF) Monitoring

The Climate and Hydrologic System



Geophysical Quantities and Units used for CHF Monitoring

<input type="checkbox"/> Solar and Terrestrial Radiation	(Watts/m ²)
<input type="checkbox"/> Surface Temperature	(Celsius or Kelvin)
<input type="checkbox"/> Rain	(mm/unit time or kg/m ² /s)
<input type="checkbox"/> Soil Moisture	(m ³ /m ³ or g/m ²)
<input type="checkbox"/> Snow/Ice	(% area cover, mm/hour)
<input type="checkbox"/> Terrain	(vertical meter)
<input type="checkbox"/> Ground Water	(m ³ or km ³)
<input type="checkbox"/> Land Cover	(Type of Land, e.g. water, forest, grass)
<input type="checkbox"/> Evapotranspiration	(mm/s or kg/m ² /s)
<input type="checkbox"/> Run off/Streamflow	(mm/s or kg/m ² /s)
<input type="checkbox"/> Winds	(m/s)
<input type="checkbox"/> Specific Humidity	(g/kg)
<input type="checkbox"/> Clouds	(% area cover)

NASA Earth Science Provides All the Geophysical Quantities for CHF Monitoring

- ☐ Solar and Terrestrial Radiation
- ☐ Rain
- ☐ Surface Temperature
- ☐ Soil Moisture
- ☐ Snow/Ice
- ☐ Clouds, Humidity
- ☐ Terrain
- ☐ Ground Water
- ☐ Land Cover
- ☐ Evapotranspiration
- ☐ Run off/Streamflow
- ☐ Winds

All these quantities are available from NASA satellite observations as well as from atmosphere-land models

Quantities in green are derived from satellite observations

Quantities in red are from land and atmosphere-land models in which satellite observations are assimilated

NASA Earth Science Provides All the Geophysical Quantities for CHF Monitoring

- ☐ Solar and Terrestrial Radiation

- ☐ Rain

- ☐ Surface Temperature

- ☐ Soil Moisture

- ☐ Snow/Ice

- ☐ Clouds, Humidity

- ☐ Terrain

- ☐ Ground Water

- ☐ Land Cover

- ☐ Evapotranspiration

- ☐ Run off/Streamflow

- ☐ Winds

This training will focus on these parameters

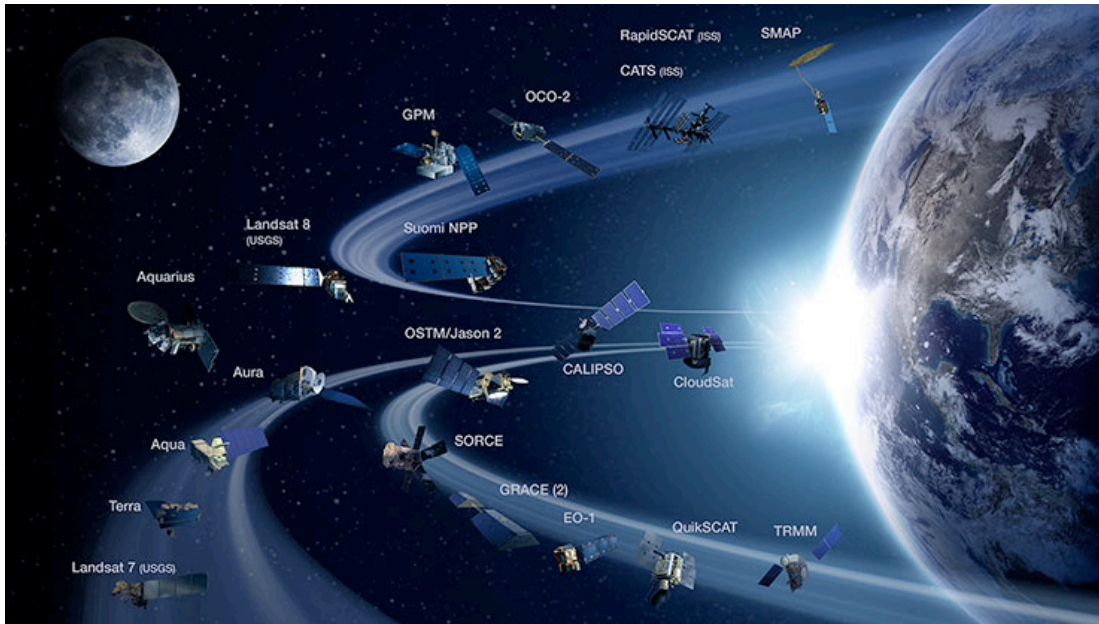
All these quantities are available from NASA satellite observations as well as from atmosphere-land models

Quantities in green are derived from satellite observations

Quantities in red are from land and atmosphere-land models in which satellite observations are assimilated

NASA Satellite Missions for CHF

NASA Earth Observing Satellites for CHF



TRMM: Tropical Rainfall Measuring Mission
GRACE: Gravity Recovery and Climate Experiment
GPM: Global Precipitation Measurements
SMAP: Soil Moisture Active Passive

Landsat (07/1972-present)

TRMM (11/1997-~~4/2015~~)

GPM (2/27/2014-present)

Terra (12/1999-present)

Aqua (5/2002-present)

SMAP (1/31/2015-present)

GRACE (3/2002-present)

NASA Earth Observing Satellites for CHF Monitoring

- Each satellite carries one or more sensors/instruments with specific spectral channels to observe specific geophysical quantities
- Sensors most used for the CHF monitoring will be described throughout this training

Landsat (07/1972-present)

TRMM (11/1997-04/2015)

GPM (2/27/2014-present)

Terra (12/1999-present)

Aqua (5/2002-present)

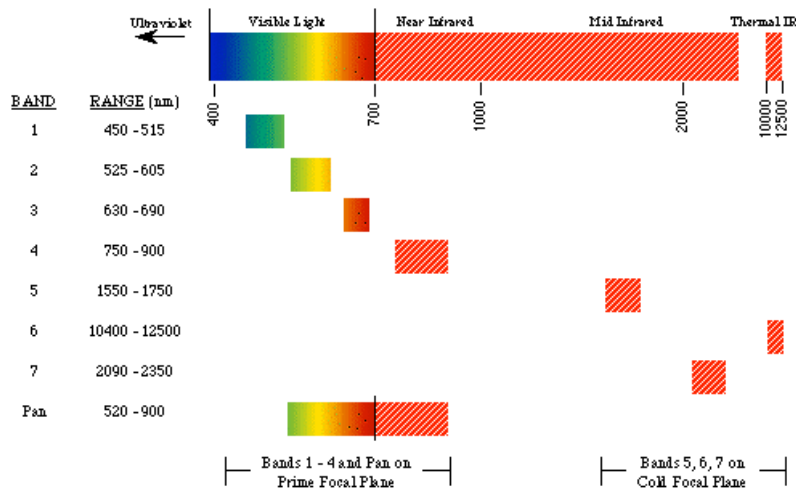
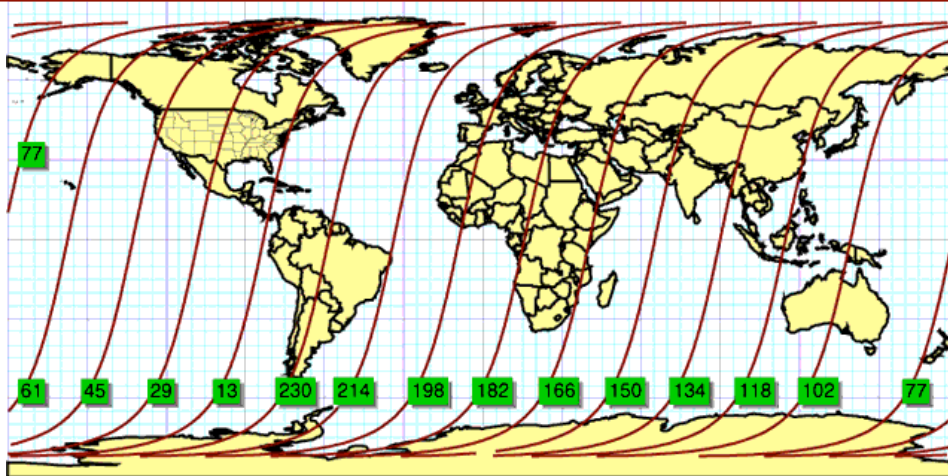
SMAP (1/31/2015-present)

GRACE (3/2002-present)

Landsat (07/1972 – Present)

<http://landsat.gsfc.nasa.gov/>

Continuous mission with multiple satellites, Landsat-1 launched in July 23, 1972



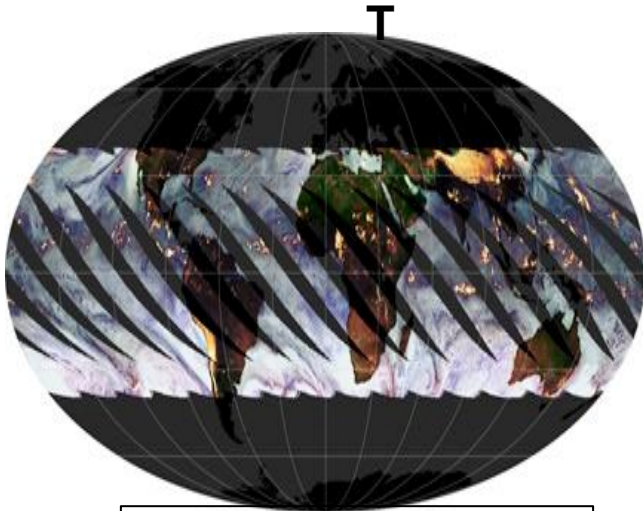
- Near-polar orbit, 10 am equator-crossing time
- Global coverage
- July 1972- Present, 16-day revisit time
- Sensors:
MSS, TM, ETM+, OLI, TIRS

Quantities:
Land Cover

TRMM (11/1997 – 4/2015)

<http://trmm.gsfc.nasa.gov>

**TRMM stopped
collecting data in April 2015**



Quantities:
Surface Rainfall
Rainfall Profiles
Latent Heating

- ❑ **A non-polar, low inclination orbit**
Revisit time ~11-12 hours, but time of the observation changes daily
- ❑ There are 16 TRMM orbits a day
covering global tropics between 35° S to 35°N latitudes
- ❑ Sensors

*Precipitation Radar (PR)**
TRMM Microwave Imager (TMI)
Visible and Infrared Scanner (VIRS)

Important Note:

TRMM mission was terminated in April 2015 but near-real time TRMM-calibrated rainfall from other satellites are available until GPM data become available in near-real time

TRMM data from 1997-2014 are widely used for weather, climate, and hydrology applications and will be used in this training

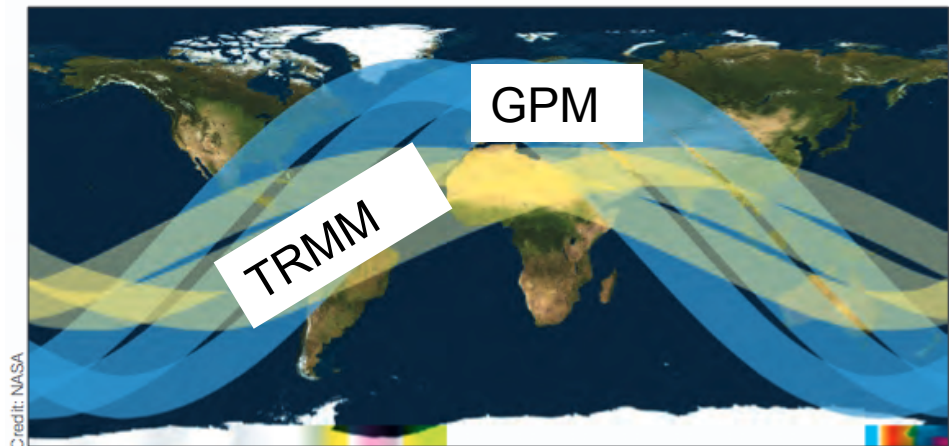
GPM (2/2014 – Present)

<http://pmm.nasa.gov/GPM>

GPM near-real time data will be available in 2016

- Non-polar, low inclination orbit with 16 orbits per day
- **GPM observes global region between 65°S to 65°N latitudes**
- Sensors:

Dual frequency Precipitation Radar (DPR)
GPM Microwave Imager (GMI)



the area covered by three TRMM orbits
[yellow] versus orbits of the GPM Core
Observatory [blue]

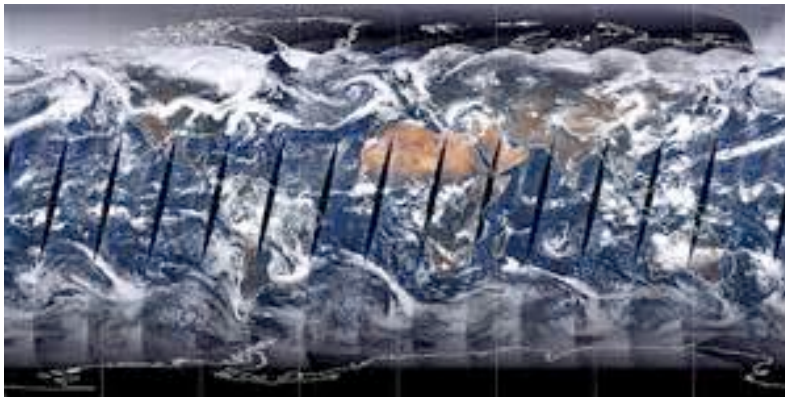
Quantities:

Surface Precipitation (Rain and Snow)

Precipitation Profiles

Terra (12/1999 – Present)

<http://terra.nasa.gov>



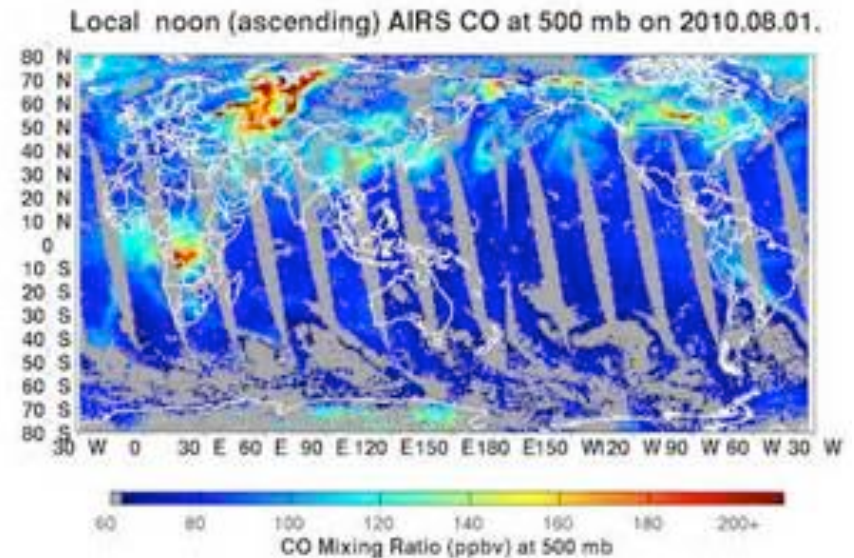
Quantities:
Land Cover
Snow Cover
Clouds
Water VApOr
Radiative Fluxes
Aerosol Information
Digital Elevation

- ❑ Polar, Sun-Synchronous Orbit, Global Coverage
- ❑ Twice-daily Observations **10:30 AM/PM** Descending Orbits
- ❑ Sensors:
 - Moderate Resolution Imaging Spectroradiometer (MODIS)
 - Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
 - Clouds and Earth's Radiant Energy System (CERES)
 - Multi-angle Imaging Spectroradiometer (MISR)
 - Measurements of Pollution in the Troposphere (MOPITT)

Aqua (5/2002 – Present)

<http://aqua.nasa.gov>

- ❑ Polar, Sun-Synchronous Orbit, Global Coverage
- ❑ Twice-daily Observations **1:30 AM/PM** Descending Orbits
- ❑ Sensors:
 - Moderate Resolution Imaging Spectroradiometer (MODIS)
 - Atmospheric Infrared Sounder (AIRS)
 - Advanced Microwave Sounding Unit (AMSU-A)
 - Advanced Microwave Scanning Radiometer for EOS (AMSR-E)
 - Clouds and the Earth's Radiant Energy System (CERES)



Quantities:

Land Cover

Snow Cover

Clouds

Temperature, Humidity

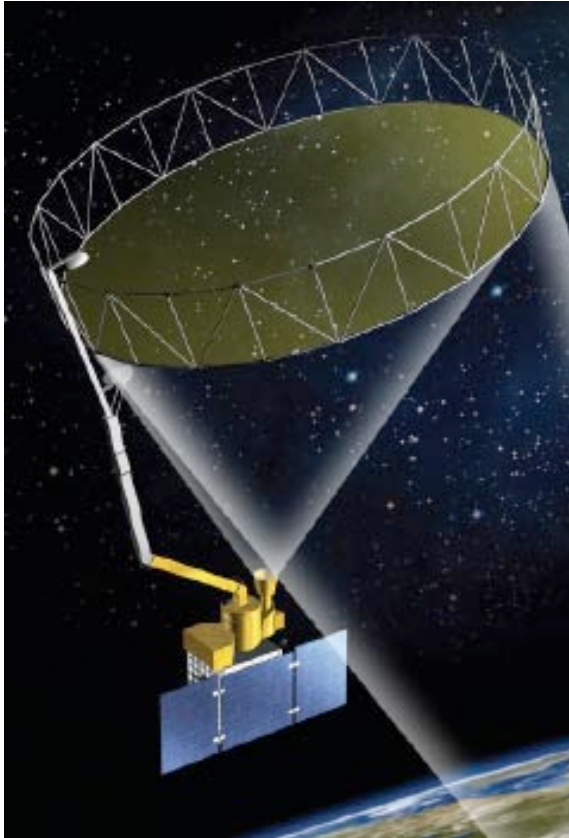
CO₂, CO, CH₄, O₃

Radiative Fluxes

Aerosol Information

SMAP (1/2015 – Present)

<http://smap.jpl.nasa.gov>

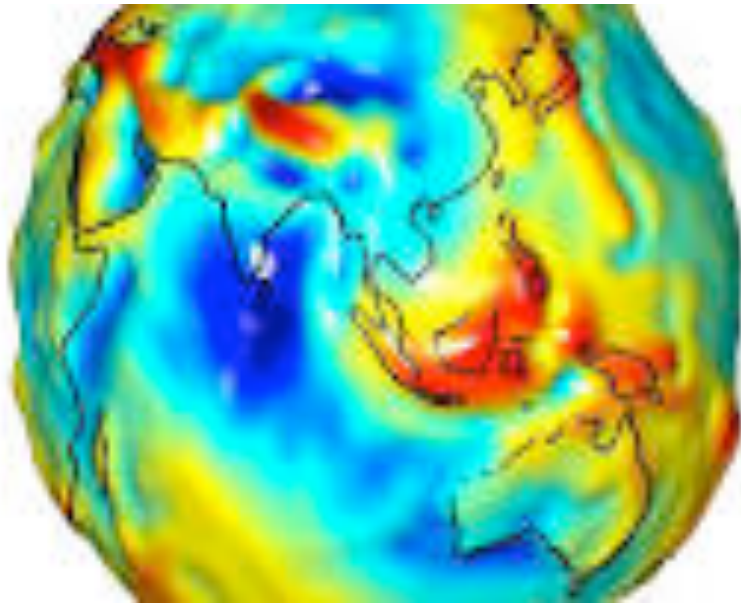


Quantities:
Soil Moisture
Freeze-Thaw State

- ❑ Polar, Sun-Synchronous Orbit, Global Coverage
- ❑ Twice-daily Observations **6:00 AM/PM** Equator Crossing
- ❑ Sensors:
 - Microwave Radiometer*
 - Microwave Radar*

GRACE (3/2002 – Present)

<http://www.jpl.nasa.gov/missions/details.php?id=5882>



Quantity:
Terrestrial Water

- ❑ Polar, Sun-Synchronous Orbit, Global Coverage
- ❑ 250 gravity profiles per day
- ❑ Sensors:
 - Microwave K-band ranging instrument*
 - Accelerometers*
 - Global Positioning System Receivers*

NASA Earth System Models for CHF Monitoring

Models Provide Value-added Information

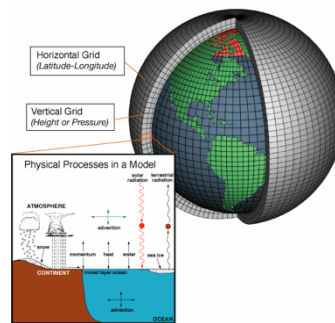
Remote Sensing + Surface Observations + Numerical Models



Satellite
Data

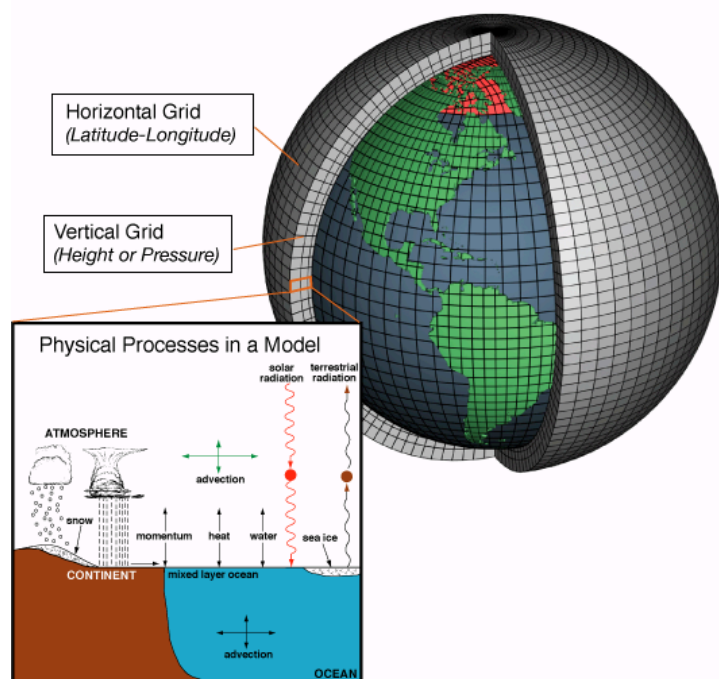


Surface
Measurements and
In-Situ Data



Numerical
Models

Modeling of the atmosphere-Land-Ocean Systems



- Models use the Laws of physics in terms of mathematical equations to represent the atmosphere, ocean, and land systems
- Applied on horizontal and vertical grids by using numerical methods
- **Models use observations to represent the atmosphere-ocean-land system at a given time to deduce how the system will evolve over space/time**
- Models use physical/statistical/empirical techniques to represent environmental processes

NASA Models for CHF Monitoring

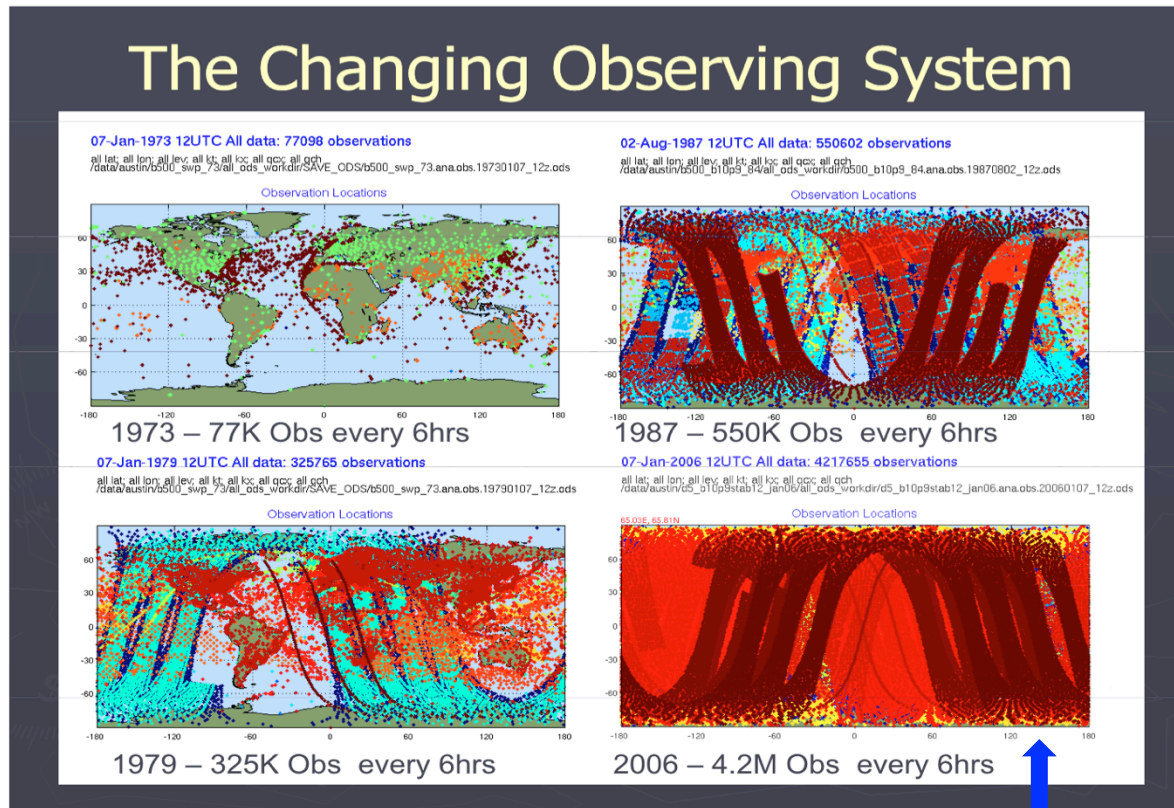
(Atmosphere-Ocean-Land Models)

- **GEOS-5** : The Goddard Earth Observing System Version 5
- **MERRA**: Modern Era Retrospective-analysis for Research and Application
- **GLDAS** : Global Land Data Assimilation System
- **NLDAS** : North American Land Data Assimilation System

MERRA

<http://gmao.gsfc.nasa.gov/merra/>

Blends the vast quantities of observational data with output data of the Goddard Earth Observing System (GEOS) model [1979-present]

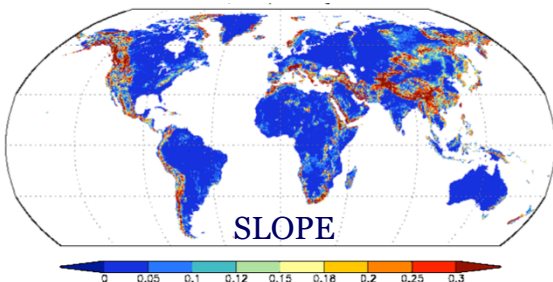
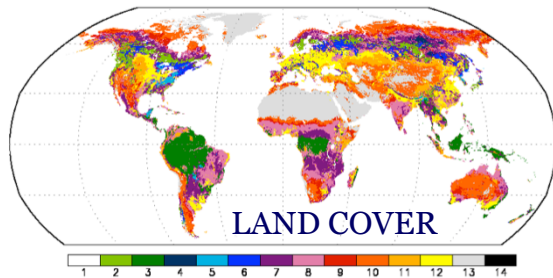
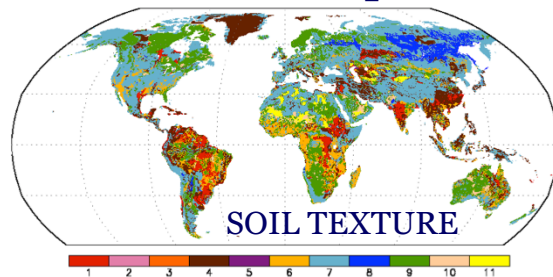


Current satellite coverage assimilated in MERRA

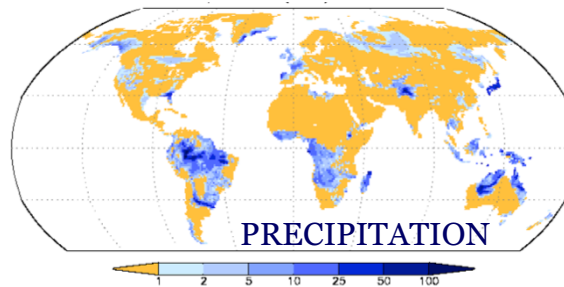
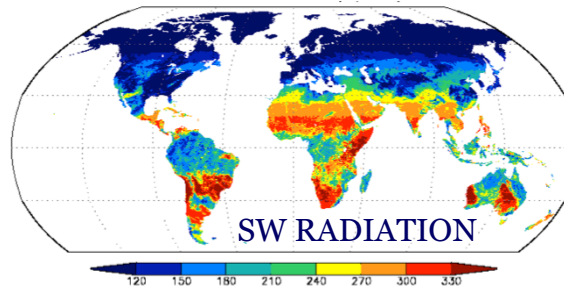
Global Land Data Assimilation System (GLDAS)

GOAL: Integrate ground and satellite observations within sophisticated numerical models to produce physically consistent, high resolution fields of land surface states (e.g., snow) and fluxes (e.g., evaporation)

Parameter Inputs

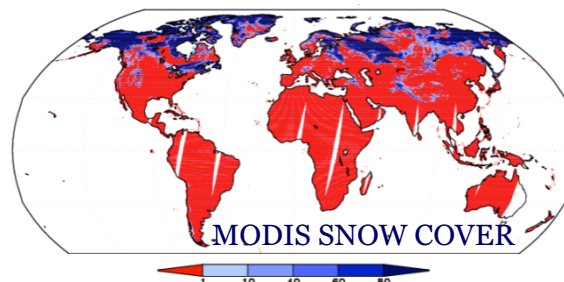


Satellite Based Forcing



AVAILABILITY: Output from 1979-present simulations of Noah ($1/4^\circ$; 1°), CLM (1°), and Mosaic (1°), and VIC (1°), are available at <http://disc.gsfc.nasa.gov/hydrology/index.shtml>

Assimilated Observations



USES: Weather and climate forecast initialization studies, water resources applications, hydrometeorological investigations

Integrated Output

Soil Moisture
Evapotranspiration
Runoff
Snow Water Equivalent

Courtesy Matt Rodell,
NASA-GSFC

<http://ldas.gsfc.nasa.gov/>

Quantities Available from Models for CHF Monitoring

Models	Quantities
MERRA	3-dimensional Winds, Temperature, Humidity, Clouds, Rain Rate ,Snow Mass, Snow Cover, Snow Depth, Surface Snowfall Rate, Evapotranspiration
GLDAS	Multi-layer Soil Moisture Evapotranspiration, Rainfall, Snowfall, Snow Melt, Snow-Water Equivalent, Surface and Sub-surface Runoff

This Training will Focus on the Following Geophysical Quantities for CHF Monitoring

<input type="checkbox"/> Surface Temperature	(Aqua/AIRS)
<input type="checkbox"/> Rain	(TRMM, GPM)
<input type="checkbox"/> Soil Moisture	(GLDAS, SMAP)
<input type="checkbox"/> Snow Cover	(Terra and Aqua MODIS)
<input type="checkbox"/> Terrain	(Shuttle Radar Topography Mission)
<input type="checkbox"/> Land Cover, Inundation	(Terra and Aqua MODIS)
<input type="checkbox"/> Run Off/Streamflow	(TRMM)
<input type="checkbox"/> Winds	(MERRA)

Data Search, Access, Analysis, and Visualization Tools

There are Multiple Web-based Tools for CHF Data Search, Analysis, and Download Options

- Mirador** For Most CHF Data Access
- Giovanni-4:** **Geospatial Interactive Online Visualization ANd
aNaLysis Infrastructure**
Selected Data Access
- PPS-STORM:** **Precipitation Processing Systems - Science Team
On-Line Request Module (STORM)**
Precipitation Data Access
- NSIDC:** **National Snow and Ice Data Center and JPL Snow
Server**
Snow and Soil Moisture Data Access
- Reverb-ECHO** Selected Data Access

Overview of the Data Tools

Tools	Data Formats	Analysis and/or Visualization	Data Download
Mirador http://mirador.gsfc.nasa.gov	HDF5, OPenDAP (can be converted to ASCII, Binary, NetCDF)	N/A	Batch Download
Giovanni http://giovanni.gsfc.nasa.gov/giovanni/	NetCDF, GeoTIFF, PNG	Visualization: Map, Time Series, Scatter Plot, Histogram Analysis: Time-averaged Maps, Time Series, Scatter Plot, Map Correlations, Vertical Profiles, Time-averaged Differences	Download by Select and Click on Data Files
PPS/STORM https://storm.pps.eosdis.nasa.gov/storm	HDF5, PNG	Map Visualization, Interactive Latitude/Longitude Point Data Value Display	FTP

Overview of the Data Tools

Tools	Data Formats	Analysis and/or Visualization	Data Download
NSIDC http://nsidc.org/	HDF5, GeoTIFF,, Binary (Data Product Dependent)	Data Search And Images	FTP Download Via Reverb
Reverb-ECHO http://reverb.echo.nasa.gov/ reverb	HDF, Image	Map Visualization	Batch Download Possible

Overview of Giovanni

Geospatial Interactive Online Visualization ANd aNalysis Infrastructure

<http://giovanni.gsfc.nasa.gov/giovanni/>

What is Giovanni?

<http://disc.sci.gsfc.nasa.gov/giovanni/overview/what-is-giovanni>

- Giovanni is an acronym for the **G**eospatial Interactive Online Visualization **A**ND **a**Nalysis Infrastructure
- Giovanni is a Web-based application developed by the Goddard Earth Sciences Data and Information Services Center (GES DISC)
- Giovanni provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data

Giovanni

<http://giovanni.gsfc.nasa.gov/giovanni/>

The screenshot shows the Giovanni web interface with several key sections highlighted by colored boxes and labeled with text:

- Analysis and Plot Selection** (Red box): Includes the "Select Plot" section with options like "Maps: Time-Averaged", "Comparisons", "Time Series", "Vertical", and "Miscellaneous".
- Spatial Selection by Map/ Latitude-Longitude Or by Shapefile** (Green box): Includes the "Select Region (Bounding Box or Shapefile)" section with a text input for coordinates and "Show Map" and "Show Shapes" buttons.
- Search Data by a Keyword** (Purple box): Includes the "Keyword" search bar and the "Number of matching Variables: 0 of 331" and "Total Variable(s) included in Plot: 0" status.
- Start and End Date Selection** (Blue box): Includes the "Select Date Range (UTC)" section with "YYYY-MM-DD" and "HH:mm" inputs and a "Valid Range: 1979-01-01 to 2015-04-08" message.
- Available Data by Disciplines** (Brown box): Includes the "Select Variables" section with "Disciplines" and "Measurements" lists.
- Plot Data** (Green box): Includes the "Plot Data" button at the bottom right.

Other visible elements include the "EARTHDATA" logo, navigation links (Data Discovery, DAACs, Community, Science Disciplines), and a "Giovanni" header with version "v 4.12" and links for "Release Notes", "Browser Compatibility", and "Known Issues".

Giovanni

<http://giovanni.gsfc.nasa.gov/giovanni/>

Select Plot
☒ **Maps: Time-Averaged** ☐ Comparisons: *Select...* ☐ Time Series: *Select...* ☐ Vertical: *Select...* ☐ Miscellaneous: *Select...*

Select Date Range (UTC)
YYYY-MM HH:mm
2014 -07 -01 04 : 00 to 2014 -07 -31 04 : 00
Valid Range: 1998-01-01 to 2014-10-31

Select Region (Bounding Box or Shapefile)
Format: West, South, East, North
-90, -55, -35, 15

Select Variables
▼ Disciplines
☐ Hydrology (4)
☐ Water and Energy Cycle (3)
▼ Measurements
☐ Precipitation (4)
► Platform / Instrument
► Spatial Resolutions
► Temporal Resolutions
► Portal

Users' Selection
Map
Time: July 2014
South America
TRMM Monthly
Total Variable(s) included in Plot: 1

Number of matching Variables: 4 of 331
Keyword : TRMM

	Variable Name	Source	Temp. Res.	Spat. Res.	Begin Date	End Date	Vert. Slice
<input checked="" type="checkbox"/>	Precipitation Rate (TRMM_3B43 v7)	TRMM	Monthly	0.25 °	1998-01-01	2014-10-31	-
<input type="checkbox"/>	Precipitation Rate (TRMM_3B43 v6)	TRMM	Monthly	0.25 °	1998-01-01	2011-06-30	-
<input type="checkbox"/>	Precipitation Rate (TRMM_3B42_daily v7)	TRMM	Daily	0.25 °	1997-12-31	2014-10-31	-
<input type="checkbox"/>	Precipitation Rate (TRMM_3B42_daily v6)	TRMM	Daily	0.25 °	1997-12-31	2011-06-30	-

Information about the Data

Giovanni

<http://giovanni.gsfc.nasa.gov/giovanni/>

Users Selection

Map
Time: July 2014
South America
TRMM Monthly

Total Variable(s) included in Plot: 1

Begin Date	End Date	Vert. Slice
1998-01-01	2014-10-31	-
1998-01-01	2011-06-30	-
1997-12-31	2014-10-31	-
1997-12-31	2011-06-30	-



Reset Feedback **Plot Data**

Select Plot

☒ Maps: Time-Averaged

☐ Comparisons: Select...

☐ Time Series: Select...

☐ Vertical: Select...

☐ Miscellaneous: Select...

Select Date Range (UTC)

YYYY-MM

HH:mm

2014 -07 -01

04 :00

to

2014 -07 -31

04 :00

Valid Range: 1998-01-01 to 2014-10-31

Select Region (Bounding Box or Shapefile)

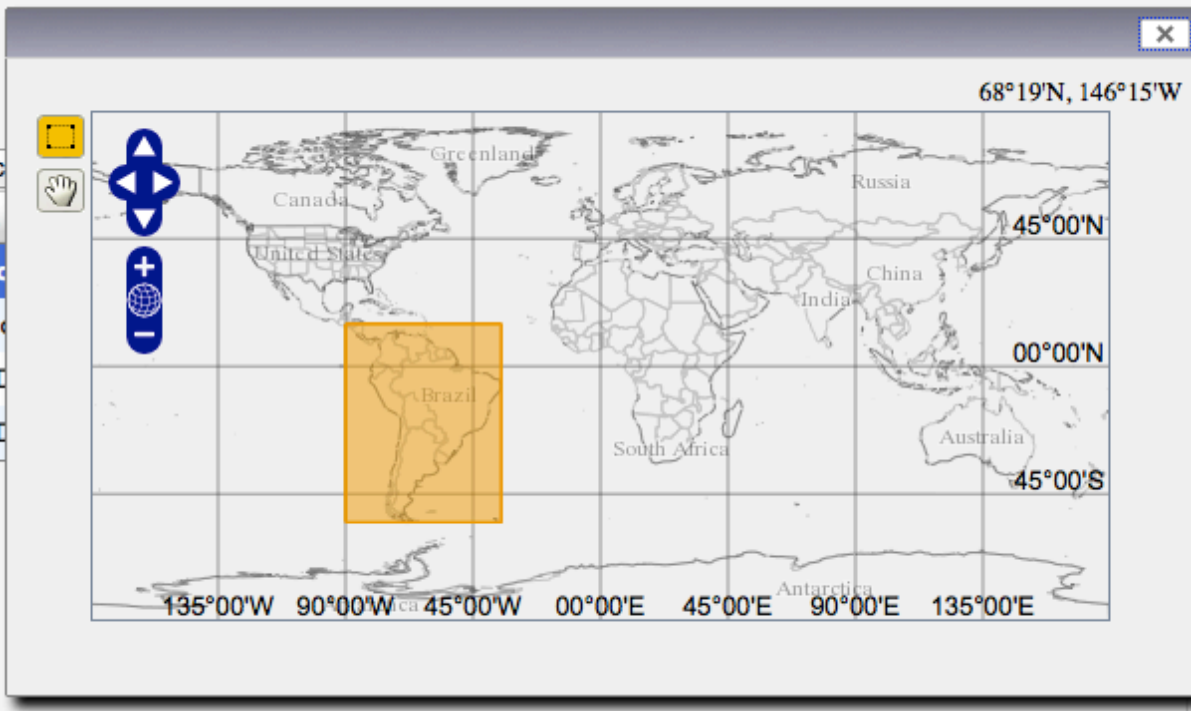
Format: West, South, East, North

-90, -55, -35, 15

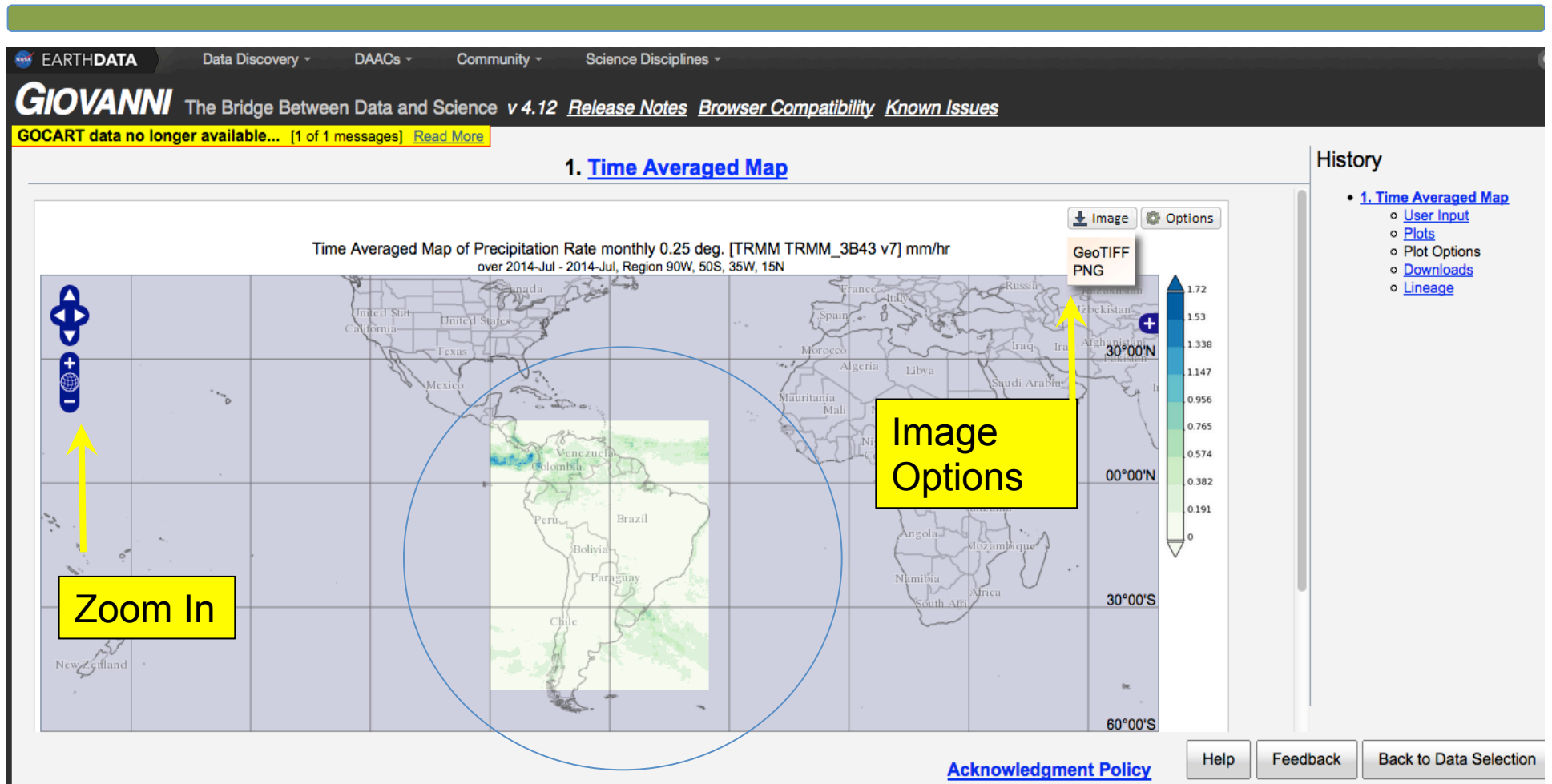
Show Map

Show Shapes

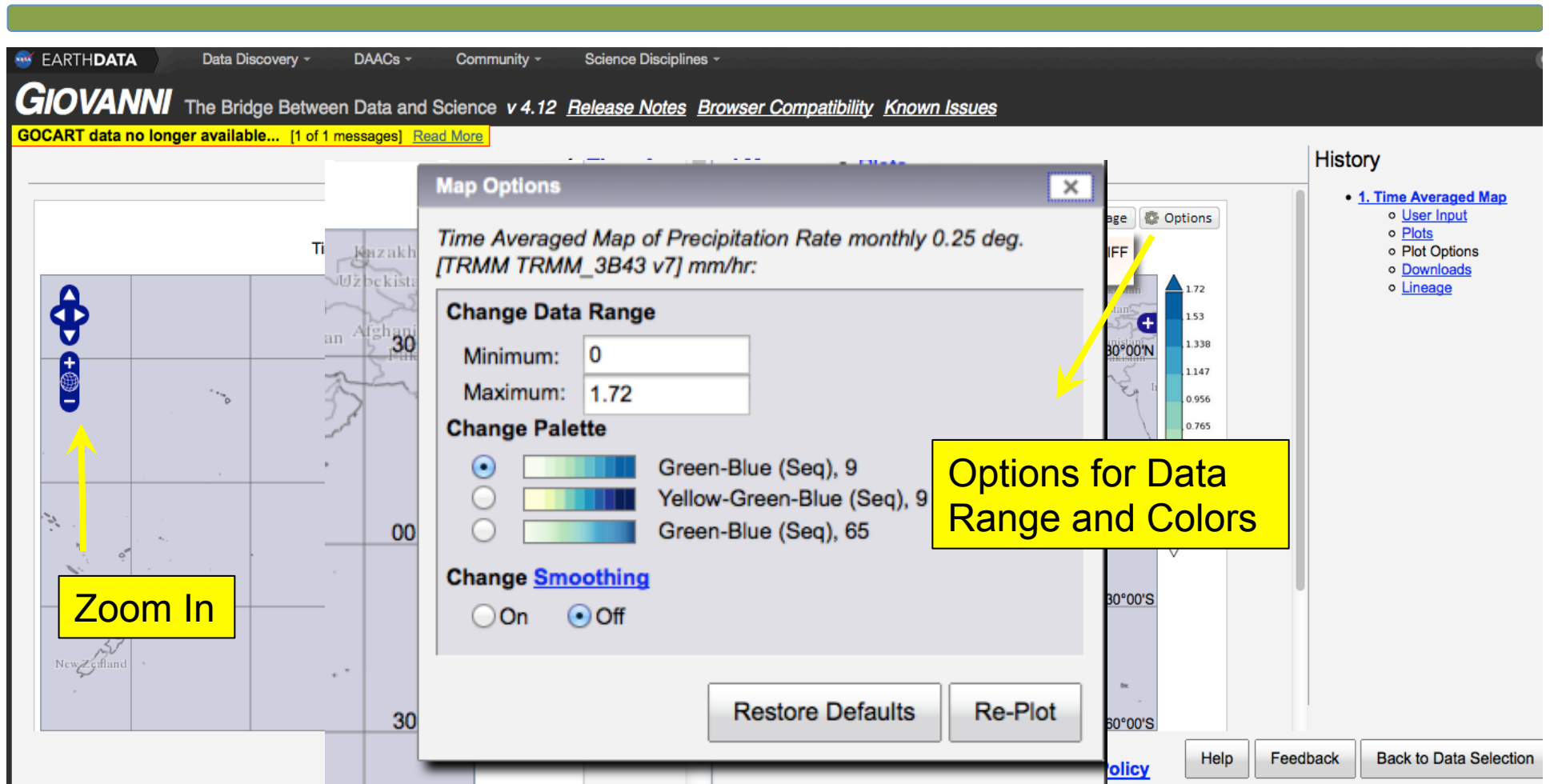
Sele



User-Selected Map from Giovanni



User-Selected Map from Giovanni



User-Selected Map from Giovanni

The screenshot displays the Giovanni web interface. At the top, the NASA EarthData logo is visible, along with navigation links for Data Discovery, DAACs, Community, and Science Disciplines. The main header reads "GIOVANNI The Bridge Between Data and Science v 4.12" with links for Release Notes, Browser Compatibility, and Known Issues. A yellow banner indicates "GOCART data no longer available... [1 of 1 messages] Read More".

The main content area is titled "1. Time Averaged Map". Below this, a message states: "Click on file links to download. Files contain data portrayed in the plot images." The download options are listed as follows:

- NetCDF Format:**
[timeAvgMap.TRMM_3B43_007_precipitation.20140701-20140731.90W_50S_35W_15N.nc](#)
- Images (GeoTIFF):**
[timeAvgMap.TRMM_3B43_007_precipitation.20140701-20140731.90W_50S_35W_15N.geotiff](#)
- Images (PNG):**
[timeAvgMap.TRMM_3B43_007_precipitation.20140701-20140731.90W_50S_35W_15N.png](#)

A red arrow points from a yellow box labeled "Options for Multiple Formats, including GeoTIFF for GIS" to the download links.

On the right side, there is a "History" panel. It contains a list of items: "1. Time Averaged Map", "User Input", "Plots", "Plot Options", "Downloads", and "Lineage". A red arrow points from a yellow box labeled "Data Download" to the "Downloads" link in the history panel.

Below the history panel, there is a yellow box labeled "Back to Data Selection". A red arrow points from this box to a button labeled "Back to Data Selection" in the footer.

The footer contains several buttons: "Acknowledgment Policy", "Help", "Feedback", "Back to Data Selection", "Feedback", and "Back to Data Selection".

Giovanni

<http://giovanni.gsfc.nasa.gov/giovanni/>

Select Plot

Maps: Time-Averaged

Comparisons: Select...

Time Series: Select...

Vertical: Select...

Miscellaneous: Select...

Select Date Range (UTC)

YYYY-MM HH:mm to YYYY-MM HH:mm

2014 -07 -01 04 : 00 to 2014 -07 -31 04 : 00

Valid Range: 1998-01-01 to 2014-10-31

Select Region (Bounding Box or Shapefile)

Format: West, South, East, North

-90, -55, -35, 15

Show Map

Show Shapes

Shape Files

Countries

US States

Shape

Chad

Chile

China

Christmas I.

Cocos Is.

Colombia

Comoros

Congo

Done

Clear Shape Selection

Users Selection

Map

Time: July 2014

South America

TRMM Monthly

Total Variable(s) included in Plot: 1

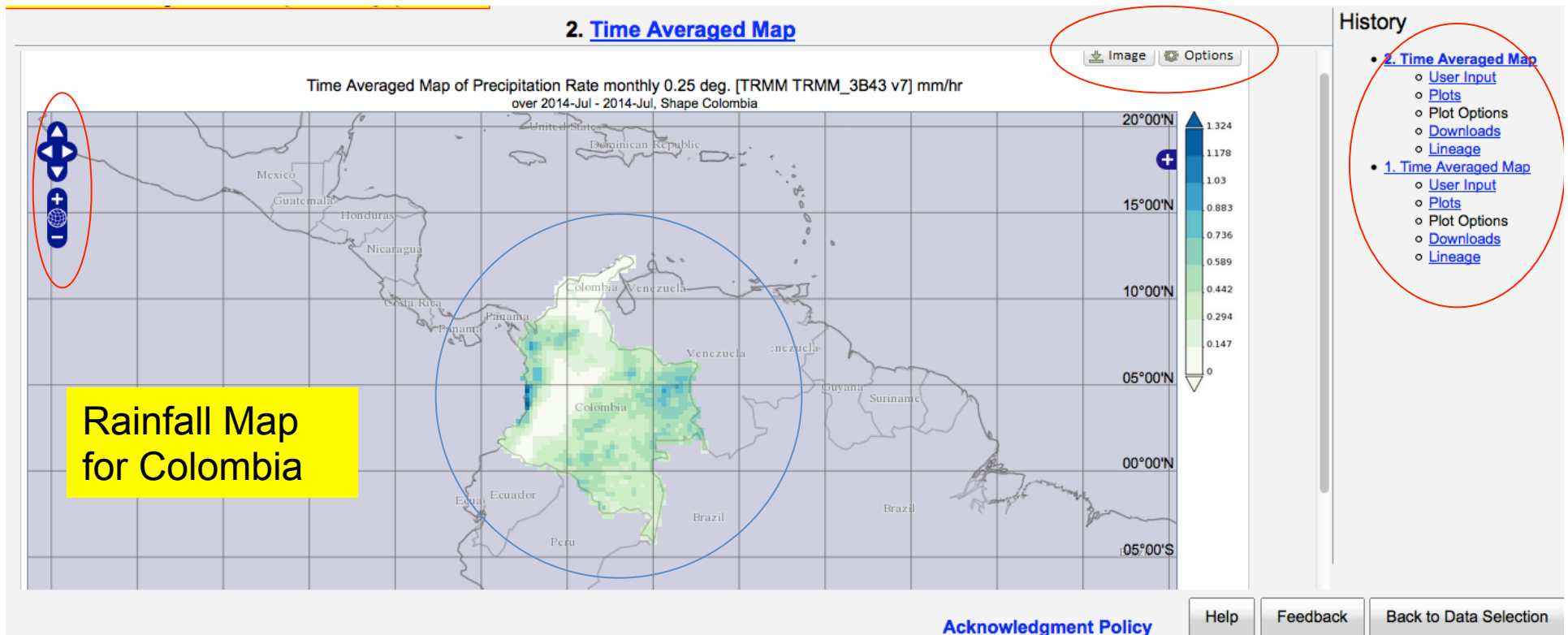
Begin Date	End Date	Vert. Slice
1998-01-01	2014-10-31	-
1998-01-01	2011-06-30	-
1997-12-31	2014-10-31	-
1997-12-31	2011-06-30	-

Reset

Feedback

Plot Data

Map for User-Selected Shapefile



Map for User-Selected Watershed

GOCART data no longer available... [1 of 1 messages] [Read More](#)

Select Plot

☒ Maps: Time Averaged Map ☐ Comparisons: Select... ☐ Time Series: Select... ☐ Vertical: Select... ☐ Miscellaneous: Select...

Select Date Range (UTC)

YYYY-MM HH:mm
2013 - 11 - 01 00:00 to 2013 - 11 - 30 23:59
Valid Range: 1997-12-01 to 2015-03-31

Select Region (Bounding Box or Shapefile)

Format: West, South, East, North
Watersheds: East Brazil, South Atl: [Show Map](#) [Show Shapes](#)

Select Variables

▼ Disciplines

- ☐ Hydrology (14)
- ☐ Water and Energy Cycle (3)

▼ Measurements

- ☐ Cloud Properties (2)
- ☐ Latent Heat (1)
- ☐ Precipitation (11)

► Platform / Instrument

► Spatial Resolutions

► Temporal Resolutions

► Portal

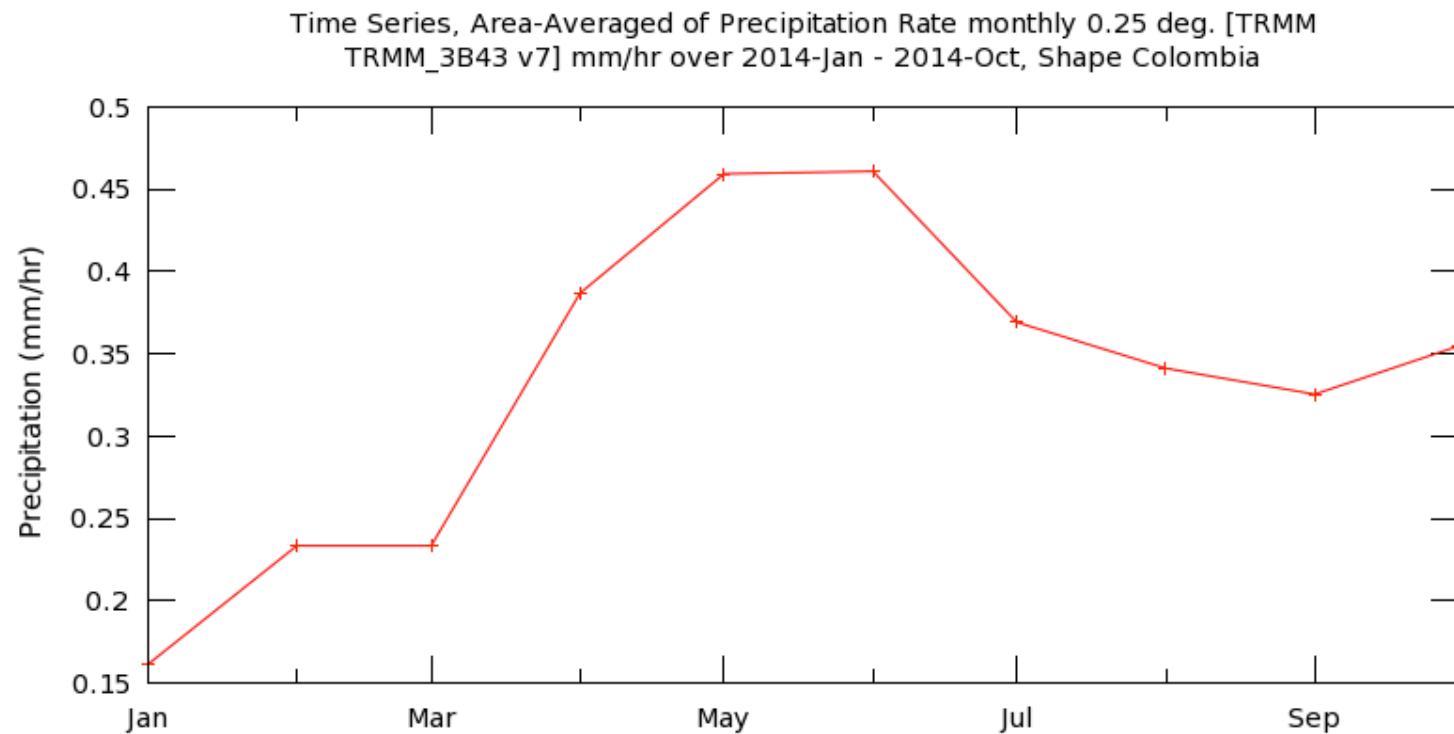
Number of matching Variables: 14 of 361

Keyword: TRMM

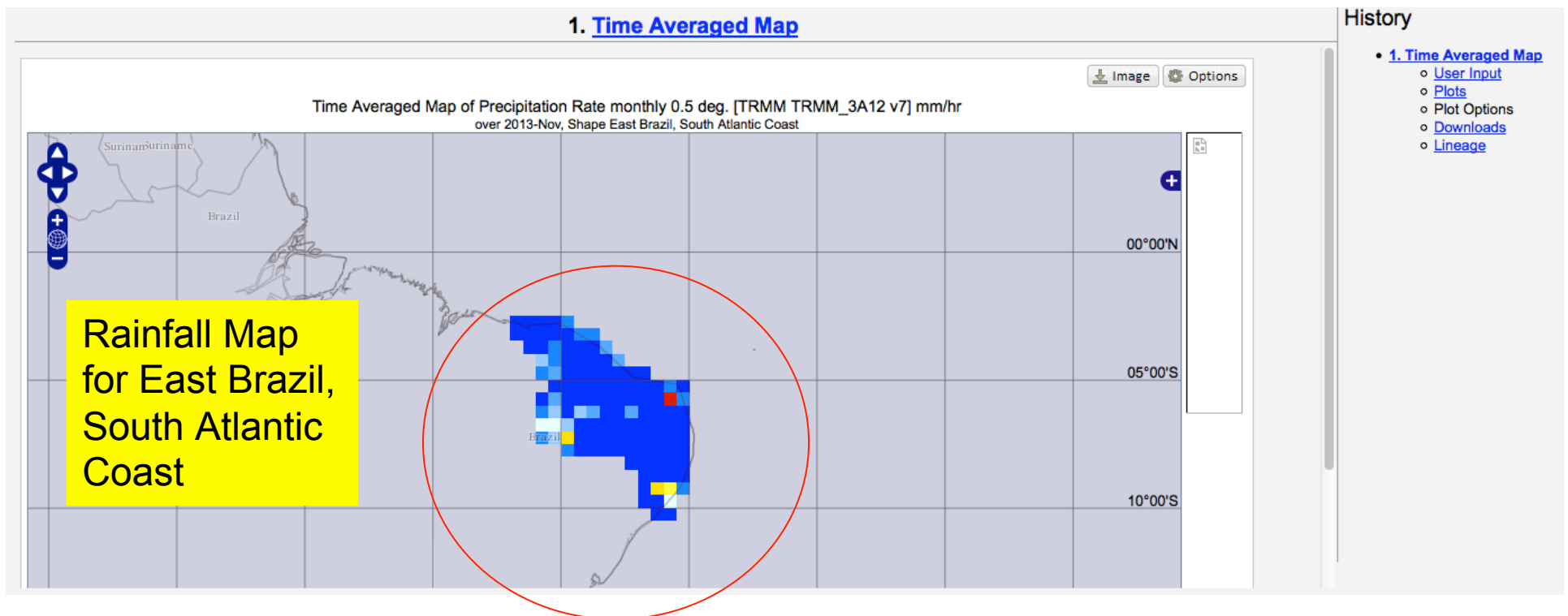
	Variable Name	Source	Temp. Res.	Spat. Res.	Begin Date	End Date	Vert. Slice
<input checked="" type="checkbox"/>	Precipitation Rate (TRMM_3A12 v7)	TRMM	Monthly	0.5 °	1997-12-01	2015-03-31	-
<input type="checkbox"/>	Precipitation Rate (TRMM_3B43 v7)	TRMM	Monthly	0.25 °	1998-01-01	2015-01-31	-
<input type="checkbox"/>	Precipitation Rate (TRMM_3B43 v6)	TRMM	Monthly	0.25 °	1998-01-01	2011-06-30	-
<input type="checkbox"/>	Cloud Ice (TRMM_3A12 v7)	TRMM	Monthly	0.5 °	1997-12-01	2015-03-31	0.5 ÷ km
<input type="checkbox"/>	Surface Convective Precipitation Rate (TRMM_3A12 v7)	TRMM	Monthly	0.5 °	1997-12-01	2015-03-31	-
<input type="checkbox"/>	Graupel (TRMM_3A12 v7)	TRMM	Monthly	0.5 °	1997-12-01	2015-03-31	0.5 ÷ km
<input type="checkbox"/>	Precipitation (Rain) (TRMM_3A12 v7)	TRMM	Monthly	0.5 °	1997-12-01	2015-03-31	0.5 ÷ km
<input type="checkbox"/>	Precipitation (Snow) (TRMM_3A12 v7)	TRMM	Monthly	0.5 °	1997-12-01	2015-03-31	0.5 ÷ km

Area-averaged Time Series Plot

3. Time Series, Area-Averaged



Map for User-Selected Watershed



Next :

Hands-on Activity to access and visualize rainfall using Giovanni